# Optimizing Thermal Processes in Waterspray Retorts

Institute for Thermal Processing Specialists
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# Why Optimize a Thermal Process?

- Reduce cycle time
  - Eliminate retorts as bottleneck
  - Increase throughput
  - Reduce overhead cost per case
- Quality Improvement
- Reduce utility costs

# Optimization Considerations

- Product
  - Conductive vs. Convective Heating
- Package
  - Rigid, semi-rigid, or flexible
  - Pressure profile to maintain container integrity
- Steam Supply
- Cooling Water
  - Seasonal water temperature
  - Recirculation systems
  - Chillers

# Optimization Focus

- Rotation
  - Determine optimal rate for heat transfer and product quality
- Heating
  - Come-up temperature profile
  - Come-up overpressure profile
- Cooling
  - Cooling temperature profile
  - Cooling pressure profile

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# Optimization Focus: Rotation

During process development, the optimal rotation rate should be determined with consideration to finding a balance between:

1. Product heating rate
2. Product quality
3. Retort mechanical reliability

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# Optimization Focus: Heating

Typically, come-up profiles rely on the steam pressure being delivered to the retort.

The following example demonstrates how increasing the steam pressure from 80 to 100 psi can reduce the cycle time by reducing the come-up time.

(Target $F_0$ = 6.0 at the end of heating)

# Normal 12' CUT

**NumeriCAL Process Calculation**

PRODUCT IDENTIFICATION | PROCESS DATA

z-Value: 18 Reference Temp: 250 Initial Temp: 90 Temp Unit: °F Simple or Broken: S

Evaluation 2-20-2009 Container Type: Container Dimension: Today: 2/20/20

| Segments | 1S | 2S | 3S | 4S | 5C | 6C | 7C | 8C | 9C |
|---|---|---|---|---|---|---|---|---|---|
| Duration (min) | 4.00 | 4.00 | 4.00 | 72.67 | 2.00 | 10.00 | 10.00 | 5.00 | 30.00 |
| RT Begin | 70.00 | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 |
| RT End | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| jh or jc | 1.91 | 1.91 | 1.91 | 1.91 | 1.56 | 1.56 | 1.56 | 1.56 | 1.56 |
| fh, f2, f3 or fc | 48.21 | 48.21 | 48.21 | 48.21 | 53.26 | 53.26 | 53.26 | 53.26 | 53.26 |
| | | | | | | | | | |
| Elapsed Time | 4.00 | 8.00 | 12.00 | 84.67 | 86.67 | 96.67 | 106.67 | 111.67 | 141.67 |
| Retort Temp | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| Product Temp | 90.00 | 90.72 | 95.65 | 243.37 | 243.82 | 243.09 | 231.61 | 220.57 | 120.37 |
| Accum F Value | 0.000 | 0.000 | 0.000 | 6.060 | 6.944 | 11.648 | 14.097 | 14.356 | 14.412 |

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OK | Cancel | Apply

# CUT Reduced to 9’

**NumeriCAL Process Calculation**

PRODUCT IDENTIFICATION | PROCESS DATA

z-Value: 18 | Reference Temp: 250 | Initial Temp: 90 | Temp Unit: °F | Simple or Broken: S

Evaluation: 2-20-2009 | Container Type: | Container Dimension: | Today: 2/20/20

| Segments | 1S | 2S | 3S | 4S | 5C | 6C | 7C | 8C | 9C |
|---|---|---|---|---|---|---|---|---|---|
| Duration (min) | 3.00 | 3.00 | 3.00 | 74.50 | 2.00 | 10.00 | 10.00 | 5.00 | 30.00 |
| RT Begin | 70.00 | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 |
| RT End | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| jh or jc | 1.91 | 1.91 | 1.91 | 1.91 | 1.56 | 1.56 | 1.56 | 1.56 | 1.56 |
| fh, f2, f3 or fc | 48.21 | 48.21 | 48.21 | 48.21 | 53.26 | 53.26 | 53.26 | 53.26 | 53.26 |
| | | | | | | | | | |
| Elapsed Time | 3.00 | 6.00 | 9.00 | 83.50 | 85.50 | 95.50 | 105.50 | 110.50 | 140.50 |
| Retort Temp | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| Product Temp | 90.00 | 90.18 | 91.95 | 243.34 | 243.78 | 243.07 | 231.59 | 220.56 | 120.36 |
| Accum F Value | 0.000 | 0.000 | 0.000 | 6.007 | 6.887 | 11.573 | 14.014 | 14.273 | 14.328 |

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# Temperature Ramp Increase

| CUT | Hold Time | Total Heating |
|---|---|---|
| 12’ | 72.67’ | 84.67’ |
| 9’ | 74.5’ | 83.5’ |

By creating a more aggressive come-up profile, the cycle time can be reduced 1.17’ in this example.

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# Optimization Focus: Cooling

Cooling water temperature has the greatest impact on the ability to optimize the cooling profile in water spray retorts.

The colder the water, the more aggressive the cooling profile can be.

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# Optimization Focus: Cooling

There are several ways to improve the cooling profile:

1. Establish multiple “recipes” for retort operation that take into account cooling water temperature throughout the year.
2. Increase the exposed surface area in heat exchangers
3. Circulate cooling water through cooling towers.
4. Incorporate chillers on the cooling water infeed line.

# Optimization Focus: Cooling

The following example demonstrates how we can reduce the cycle time by using colder water to achieve container center temperatures of 120° at the end of the process.

# Typical Cooling Profile
# Cooling Water Temperature = 70°F

**NumeriCAL Process Calculation**

PRODUCT IDENTIFICATION | PROCESS DATA

z-Value: 18 Reference Temp: 250 Initial Temp: 90 Temp Unit: °F Simple or Broken: S

Evaluation 2-20-2009 Container Type: Container Dimension: Today: 2/20/20

| Segments | 1S | 2S | 3S | 4S | 5C | 6C | 7C | 8C | 9C |
|---|---|---|---|---|---|---|---|---|---|
| Duration (min) | 4.00 | 4.00 | 4.00 | 72.67 | 2.00 | 10.00 | 10.00 | 5.00 | 30.00 |
| RT Begin | 70.00 | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 |
| RT End | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| jh or jc | 1.91 | 1.91 | 1.91 | 1.91 | 1.56 | 1.56 | 1.56 | 1.56 | 1.56 |
| fh, f2, f3 or fc | 48.21 | 48.21 | 48.21 | 48.21 | 53.26 | 53.26 | 53.26 | 53.26 | 53.26 |
| | | | | | | | | | |
| Elapsed Time | 4.00 | 8.00 | 12.00 | 84.67 | 86.67 | 96.67 | 106.67 | 111.67 | 141.67 |
| Retort Temp | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| Product Temp | 90.00 | 90.72 | 95.65 | 243.37 | 243.82 | 243.09 | 231.61 | 220.57 | 120.37 |
| Accum F Value | 0.000 | 0.000 | 0.000 | 6.060 | 6.944 | 11.648 | 14.097 | 14.356 | 14.412 |

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OK | Cancel | Apply

# Cooling Profile with Cooling Water Temperature = 50°F

**NumeriCAL Process Calculation**

PRODUCT IDENTIFICATION | PROCESS DATA

z-Value: 18 | Reference Temp: 250 | Initial Temp: 90 | Temp Unit: °F | Simple or Broken: S

Evaluation: 2-25-2009 | Container Type: | Container Dimension: | Today: 2/25/20

| Segments | 1S | 2S | 3S | 4S | 5C | 6C | 7C | 8C | 9C |
|---|---|---|---|---|---|---|---|---|---|
| Duration (min) | 4.00 | 4.00 | 4.00 | 72.67 | 2.00 | 10.00 | 10.00 | 5.00 | 25.50 |
| RT Begin | 70.00 | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 50.00 |
| RT End | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 50.00 | 50.00 |
| jh or jc | 1.91 | 1.91 | 1.91 | 1.91 | 1.56 | 1.56 | 1.56 | 1.56 | 1.56 |
| fh, f2, f3 or fc | 48.21 | 48.21 | 48.21 | 48.21 | 53.26 | 53.26 | 53.26 | 53.26 | 53.26 |
| | | | | | | | | | |
| Elapsed Time | 4.00 | 8.00 | 12.00 | 84.67 | 86.67 | 96.67 | 106.67 | 111.67 | 137.17 |
| Retort Temp | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 50.00 | 50.00 |
| Product Temp | 90.00 | 90.72 | 95.65 | 243.37 | 243.82 | 243.09 | 231.61 | 220.51 | 120.33 |
| Accum F Value | 0.000 | 0.000 | 0.000 | 6.060 | 6.944 | 11.648 | 14.097 | 14.356 | 14.409 |

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OK | Cancel | Apply

# Effect of Cooling Water Temperature Reduction

| Cooling Water Temperature | Total Cooling Time |
|---|---|
| 70°F | 57’ |
| 50°F | 52.5’ |

Without modifying the cooling ramp profile, we can realize a 4.5’ reduction in cycle time by lowering the cooling water temperature by 20°F.

# Optimization Focus: Cooling

Based on the capability of the retort, there may be more opportunities to reduce the cooling time through more aggressive cooling ramp steps.

Testing in the plant is necessary to determine just how aggressive the cooling ramp can be.

# F-value at the End of Heating

One other salvo in our arsenal for optimizing thermal processes rests with our risk tolerance position.  Targeting a lower F-value at the end of heating can also reduce cycle time.

# Considerations for Reducing Target F-value at the End of Heating

- Confidence in the maintenance of machinery
- Ability to control critical factors upstream of the retort
- Confidence in the heating rate of the product determined through HP tests
- Company's risk tolerance position

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# Effect of Reducing End of Heating F-value

Provided there is confidence that the previously mentioned considerations have been addressed, the following example demonstrates the amount of time that can be reduced from a cycle by reducing the end of heating $F_0$ to 3.0’ from 6.0’:

# Starting Process

# $F_0$ = 6.0' at end of heating

**NumeriCAL Process Calculation**

PRODUCT IDENTIFICATION | PROCESS DATA

z-Value: 18 | Reference Temp: 250 | Initial Temp: 90 | Temp Unit: °F | Simple or Broken: S

Evaluation 2-20-2009 | Container Type: | Container Dimension: | Today: 2/20/20

| Segments | 1S | 2S | 3S | 4S | 5C | 6C | 7C | 8C | 9C |
|---|---|---|---|---|---|---|---|---|---|
| Duration (min) | 4.00 | 4.00 | 4.00 | 72.67 | 2.00 | 10.00 | 10.00 | 5.00 | 30.00 |
| RT Begin | 70.00 | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 |
| RT End | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| jh or jc | 1.91 | 1.91 | 1.91 | 1.91 | 1.56 | 1.56 | 1.56 | 1.56 | 1.56 |
| fh, f2, f3 or fc | 48.21 | 48.21 | 48.21 | 48.21 | 53.26 | 53.26 | 53.26 | 53.26 | 53.26 |
| | | | | | | | | | |
| Elapsed Time | 4.00 | 8.00 | 12.00 | 84.67 | 86.67 | 96.67 | 106.67 | 111.67 | 141.67 |
| Retort Temp | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| Product Temp | 90.00 | 90.72 | 95.65 | 243.37 | 243.82 | 243.09 | 231.61 | 220.57 | 120.37 |
| Accum F Value | 0.000 | 0.000 | 0.000 | 6.060 | 6.944 | 11.648 | 14.097 | 14.356 | 14.412 |

Spread | Clear | Import | Print | Evaluate | tp calc

OK | Cancel | Apply

# Revised Process

# $F_0$ = 3.0' at end of heating

**NumeriCAL Process Calculation**

PRODUCT IDENTIFICATION | PROCESS DATA

z-Value: 18 — Reference Temp: 250 — Initial Temp: 90 — Temp Unit: °F — Simple or Broken: S

Evaluation: 2-20-2009 — Container Type: — Container Dimension: — Today: 2/20/20

| Segments | 1S | 2S | 3S | 4S | 5C | 6C | 7C | 8C | 9C |
|---|---|---|---|---|---|---|---|---|---|
| Duration (min) | 4.00 | 4.00 | 4.00 | 64.17 | 2.00 | 10.00 | 10.00 | 5.00 | 30.00 |
| RT Begin | 70.00 | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 |
| RT End | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| jh or jc | 1.91 | 1.91 | 1.91 | 1.91 | 1.56 | 1.56 | 1.56 | 1.56 | 1.56 |
| fh, f2, f3 or fc | 48.21 | 48.21 | 48.21 | 48.21 | 53.26 | 53.26 | 53.26 | 53.26 | 53.26 |
| | | | | | | | | | |
| Elapsed Time | 4.00 | 8.00 | 12.00 | 76.17 | 78.17 | 88.17 | 98.17 | 103.17 | 133.17 |
| Retort Temp | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 70.00 | 70.00 |
| Product Temp | 90.00 | 90.72 | 95.65 | 240.09 | 240.75 | 240.89 | 229.96 | 219.13 | 119.54 |
| Accum F Value | 0.000 | 0.000 | 0.000 | 3.033 | 3.623 | 6.996 | 8.901 | 9.114 | 9.161 |

Spread | Clear | Import | Print | Evaluate | tp calc

OK | Cancel | Apply

# Effect of Reducing End of Heating F-value

| End of Heating $F_0$ | Process 'Hold' Time |
|---|---|
| 6.0' | 72.67' |
| 3.0' | 64.17' |

By reducing the target F-value at the end of heating, an 8.5' reduction in heating time could be realized on each cycle. The downside is that the amount of extra lethality is also reduced, thus providing less cushion, should there be a process deviation.

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# Optimized Process

So how much cycle time can be claimed if we optimize the come-up, end of heating F-value, and cooling water temperature?

Let's take a look at the original process compared to a process with improved come-up, that delivers $F_0$ = 6.0' at the end of the second cooling step and a final container center temperature of 120°F

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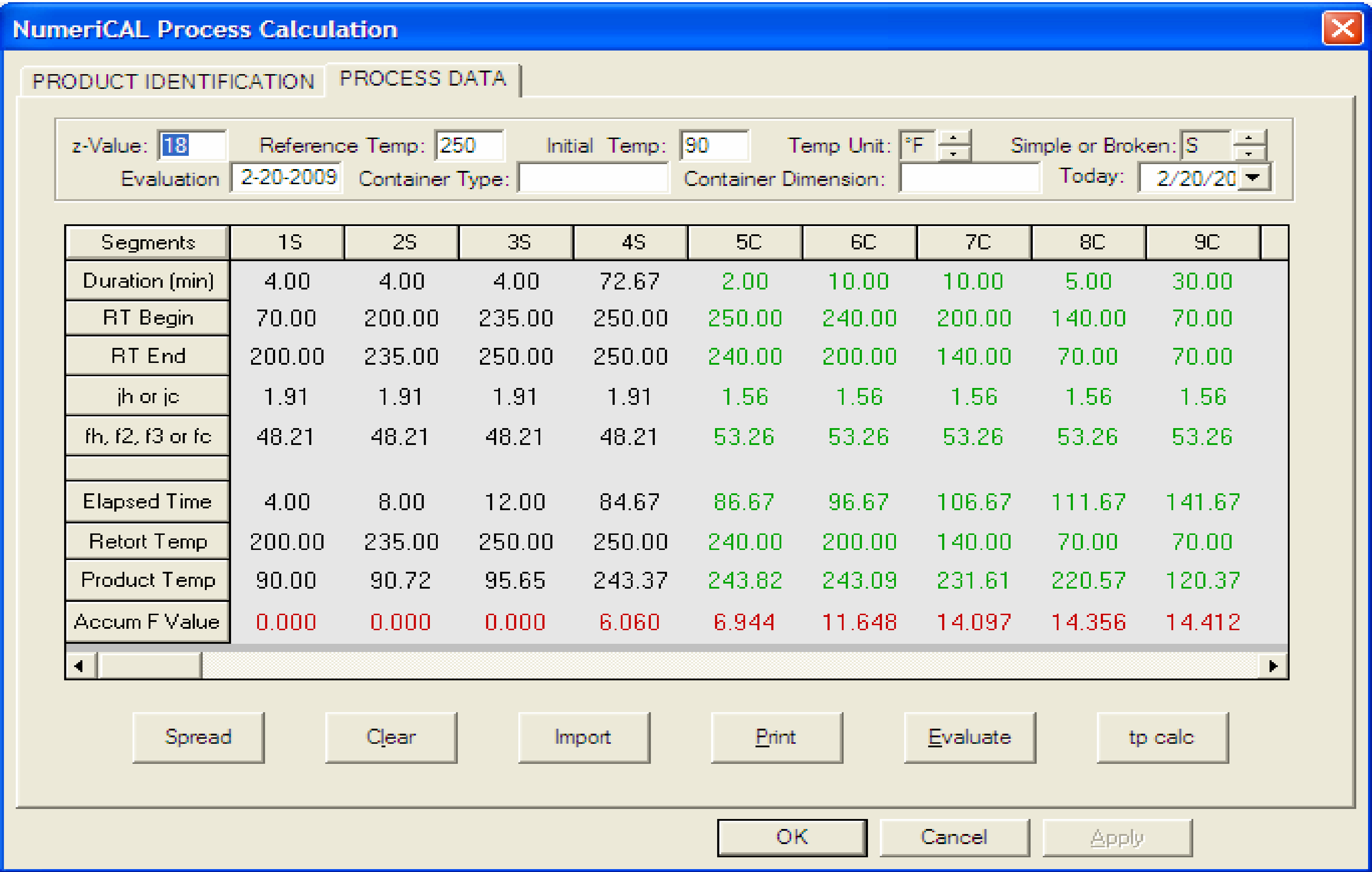
# Original Process



# Optimized Process

**NumeriCAL Process Calculation**

PRODUCT IDENTIFICATION | PROCESS DATA

z-Value: 18 Reference Temp: 250 Initial Temp: 90 Temp Unit: °F Simple or Broken: S

Evaluation 2-20-2009 Container Type: Container Dimension: Today: 2/20/20

| Segments | 1S | 2S | 3S | 4S | 5C | 6C | 7C | 8C | 9C |
|---|---|---|---|---|---|---|---|---|---|
| Duration (min) | 3.00 | 3.00 | 3.00 | 64.17 | 2.00 | 10.00 | 10.00 | 5.00 | 25.00 |
| RT Begin | 70.00 | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 50.00 |
| RT End | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 50.00 | 50.00 |
| jh or jc | 1.91 | 1.91 | 1.91 | 1.91 | 1.56 | 1.56 | 1.56 | 1.56 | 1.56 |
| fh, f2, f3 or fc | 48.21 | 48.21 | 48.21 | 48.21 | 53.26 | 53.26 | 53.26 | 53.26 | 53.26 |
| | | | | | | | | | |
| Elapsed Time | 3.00 | 6.00 | 9.00 | 73.17 | 75.17 | 85.17 | 95.17 | 100.17 | 125.17 |
| Retort Temp | 200.00 | 235.00 | 250.00 | 250.00 | 240.00 | 200.00 | 140.00 | 50.00 | 50.00 |
| Product Temp | 90.00 | 90.18 | 91.95 | 239.13 | 239.86 | 240.24 | 229.48 | 218.64 | 120.70 |
| Accum F Value | 0.000 | 0.000 | 0.000 | 2.512 | 3.036 | 6.098 | 7.868 | 8.069 | 8.111 |

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OK | Cancel | Apply

# Total Cycle Time Comparison

| Process | Heating | Cooling | Total Cycle |
|---|---|---|---|
| Original | 84.67’ | 57’ | 141.67’ |
| Optimized | 73.17’ | 52’ | 125.17’ |

By optimizing the original process, we can realize a 16.5’ or 11.65% reduction in cycle time. This equates to one extra cycle for every 9 cycles processed.

# Proceed with Caution!

A few key points to keep in mind:

1. When optimizing, take small steps since container integrity must also be verified throughout the testing.
2. Overpressure ramps may also need to be modified.
3. Involve other disciplines in the optimization process.  Going too far can easily create problems for Operations and QC personnel.

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# Thank You!